Irrigation Water Use – Drip v. Surface Irrigation of Onions

Interim Draft Report Utah Agricultural Water Optimization

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Introduction

Agriculture water optimization is important in Utah due to increased water needs, limited water supply, and uncertain climate changes which may affect water supplies. Water shortages that can dramatically affect agricultural, municipal, and environmental users. Agriculture diverts about 80 percent of all diversion in Utah. Utah House Bill 381, Agricultural Water Optimization includes directives and funds for assessing applicable agriculture irrigation water conservation technology (Utah Legislature, 2018). An Agriculture Water Optimization study which began in 2019 is to determine differences in consumptive water use or depletion between drip and surface irrigation onions. Onions were selected because Utah growers currently use both drip and surface irrigation.

Agriculture water optimization in Utah is more complicated than irrigation efficiencies. Much of the state is within closed basins where water flows to terminus water bodies or playas. For example, the Great Salt Lake which supports significant industries requires adequate water to protect environmental resources and air quality. In many areas of Utah, irrigation diversions provide water for crop production and return flows or groundwater recharge for other water users. Without proper consideration improving irrigation efficiency can increase consumptive use and impair water rights of others or be harmful for the environment (Grafton, Et al, 2018). For this reason, depletion from irrigation is emphasized.

Drip irrigation is a good candidate for agriculture water optimization, because drip irrigation can maintain or improve crop production while consuming less water. Drip irrigation is used on commercial onions in Box Elder and Weber County, Utah. Properly managed, drip irrigation provides excellent water management capabilities, helps control weeds, improves yields and onion size uniformity, reduces labor when compared to furrow irrigation, reduces fertilizer input, and significantly reduces irrigation diversions by eliminating tail-water runoff and minimizing deep percolation (Shock, et al., 2013, Enciso, et al., 2015, and Maughan, et al, 2015). Onion yield and quality is sensitive to soil water availability and onions have a shallow rooting zone. The acreage of drip-irrigated onions in Utah is expanding each year as growers seek to improve yields and profits. This research quantifies water depletion (consumptive use) from drip irrigation onions and compares it to the water use of traditional furrow-irrigated onions. This report is based on data collected in 2019, additional studies are being conducted in 2020.

Estimates of ET and net irrigation requirements of onions in Box Elder County are published in a 2011 consumptive use report prepared by Utah Agriculture Experiment Station (Utah, 2011). Table 1 summarizes the USU electronic weather station estimates are based on a Penman equation reference ET and crop coefficients and the National Weather Service are based on a calibrated NRCS Blaney-Criddle equation. The crop ET based methods and averages are 28.97 and 31.85 inches, and the net irrigation requirements (depletion) are 23.97 and 28.83 inches (Utah DNR, 2011). These values are not based on field measurements in Utah.

Table 1. Published estimated crop based on weather data, reference ET and crop coefficients.

	MAR	APR	MAY	JUN	JUL	AUG	SEP	**TOTAL**
Tremonton USU Electronic Weather Station (2003-2010)								
Crop ET (in.)	0.02	3.02	6.18	10.56	8.95	3.12		**31.85**
Net Irrigation (in.)		1.42	5.34	10.49	8.58	2.99		**28.83**
Tremonton National Weather Service Site (1971-2008)								
Crop ET (in.)		1.81	4.87	9.81	9.11	3.32	0.05	**28.97**
Net Irrigation (in.)		0.06	4.05	9.1	8.45	2.31		**23.97**

Transpiration of crops is closely related to yield of crops, while decreased irrigation can reduce transpiration it can also reduce yields. Water consumptive use that is not crop transpiration includes evaporation from soil, open water, sprinkler spray, and ET of weeds, ditch and drain bank vegetation. Yield is a function of many processes and inputs, with transpiration by the crop being a factor. Irrigation provides water for transpiration; however, irrigation water also evaporates from the soil and other surfaces and can leave the field by runoff and/or deep percolation.

Drip irrigation usually increases the fraction of the water applied used for crop transpiration and yield. For onions, the drip tape is generally placed a few inches under the soil surface and only wets a portion of the soil surface (Figure 1). The irrigation frequency of drip irrigation can be a couple of days to a week, while for surface it is not practical to irrigate as often and can be limited by irrigation turns (predetermined schedule). For onions, surface irrigation wets most of the ground surface as water seeps from the furrow to beds (Figure 1).

Figure 1. Sub-surface drip (left) and surface irrigated onions (right) in West Weber, Utah (2019).

Other components of the onion irrigation water budget include deep percolation and ET contribution from shallow groundwater. The deep percolation was estimated using data from the soil water sensors. In many locations most of the water leaving the field as deep percolation or surface runoff returns to the surface or groundwater system and can be available for other uses. In some cases, a portion of the non-consumptive field losses can be lost to the atmosphere by increase consumptive use in drains and waterways or become part of water sources that are not available for other water users.

Methodology

The water balance method of estimating ET was selected as most suitable for this research. The simplest field level water balance is ET from irrigation is equal to irrigation inflow minus irrigation outflow (runoff and deep percolation), minus increase in soil water storage. Additional refinement of this method is accomplished through a soil water budget which can be conducted on a smaller time scale (e.g. 30-minutes) and provide data to estimate deep percolation. The inflow can be expanded to include precipitation and groundwater contributions, and the outflow can include deep percolation. Evaporation from wet soils, vegetative surfaces, open water, and from water sprayed with sprinkler irrigation is estimated as the difference between irrigation diversions and water measured in the soil, calculated ET, deep percolation and runoff. The ET equation from the soil water budget is:

> ET = Irrigation + Precipitation + Groundwater contribution– Deep percolation ± change in soil moisture;

Units of are measured in volume and then converted to a depth by dividing by and area. This study uses depth in inches.

- Irrigation was measured by flow meters, rain gages, increase in soil water during irrigation, or drip tape discharge.
- Precipitation measured by rain gages.
- Groundwater contribution are part of irrigation water or negligible due to depth of water table.
- Deep percolation estimated by measured changes soil moisture (e.g. decreases in soil moisture that are greater than available energy to transpire or evaporate water).
- Changes in soil water measured by soil moisture sensors.

The water balance components are show in Figure 2.

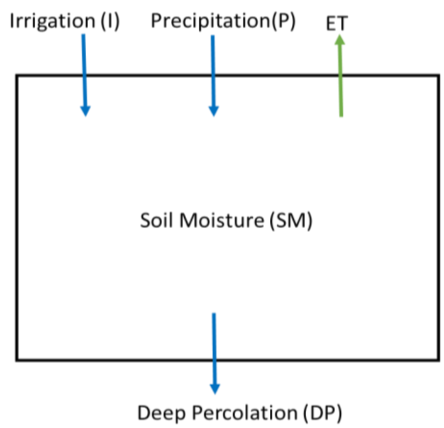

Figure 2. Simple soil water budget indicating major inputs, outputs, and soil water. No contribution from groundwater is assumed.

There are several considerations when using the soil water budget. First the measurements are point locations and there are differences in the field. However, using several locations provides a good estimate of ET, especially if the locations provide the same results. The basic equation is shown below. At a point measurement the soil moisture is measured; the irrigation and deep percolation is not measured.

$$ET = SM_{beg} – SM_{end} + I + P – DP \text{ (as defined in Figure 2)}$$

Because there are several unknowns, unknown variables must be isolated and solved for separately. ET can be directly estimated for times (hours and days) when there is no irrigation, precipitation or deep percolation. This condition is the most common condition in an arid area like Utah and provides the best ET data. Soil moisture (SM) decreases during the day at the rate that water is removed from the soil for ET.

$$ET_{est} = SM_{beg} – SM_{end}$$

An irrigation or precipitation event occurred if $SM_{beg} < SM_{end,}$ then SM was added by irrigation or precipitation. We know from weather data and irrigation flow measurement data when this occurs. In this case there are three unknowns in the soil water budget (ET, P, I). We can use the weather station data to determine if a precipitation event occurred and the approximate amount. Now there are *two unknowns* and only one equation. In this case the average ET when irrigation and/or precipitation did *not* occur before and after the irrigation and/or precipitation event can be used to estimate ET for the day; or ET can be estimated from a reference ET equation that uses the weather data and crop coefficients (Kc = ET/ETo) calculated from periods before and after the irrigation and/or precipitation events. Furthermore, the total irrigation is known due to inflow and outflow measurements, but the infiltrated irrigation a point is not certain. The equation is rearranged as follows:

$$I = SM_{end} – SM_{beg} + ET_{est} \text{ (where } ET_{est} \text{ is estimated as described above).}$$

Deep percolation after an irrigation or precipitation can be estimated. If ET calculated from soil moisture is more than ET_{est} then SM was also removed by deep percolation to the water table. For example, if ET calculated from SM is 0.75 in/day and estimated ET is 0.3 in/day, then deep percolation occurred. This can also be observed from plots of the soil moisture data. Deep percolation is then estimated by the following equation. Deep percolation can continue a day or more after an irrigation. The equation is rearranged as follows:

$$DP = SM_{beg} – SM_{end} + I + P – ET_{est}$$

Other considerations include the soil moisture budget <u>does not fully account for evaporation from the soil surface</u> and <u>plant water use in the top inch or so of the soil</u>. The soil moisture sites were equipped with near infrared radiometers to measure soil/canopy temperature. This data can be used to estimate soil evaporation using an energy balance. Other data measured by sensors include soil temperature, soil water electrical conductivity, and soil matrix electrical conductivity. The temperature data is used for the energy balance and the salinity data is used for irrigation management. Another source of water for plant ET is contributions from groundwater. There are a few methods to estimate the contributions from groundwater, but this component was not apparent in West Weber fields.

Field Research Layout

A surface and drip irrigated onion field located in West Weber were selected for 2019 research. Figures 1 (surface irrigation) and 2 (drip irrigation) show the fields and the location of the sensors and flowmeters.

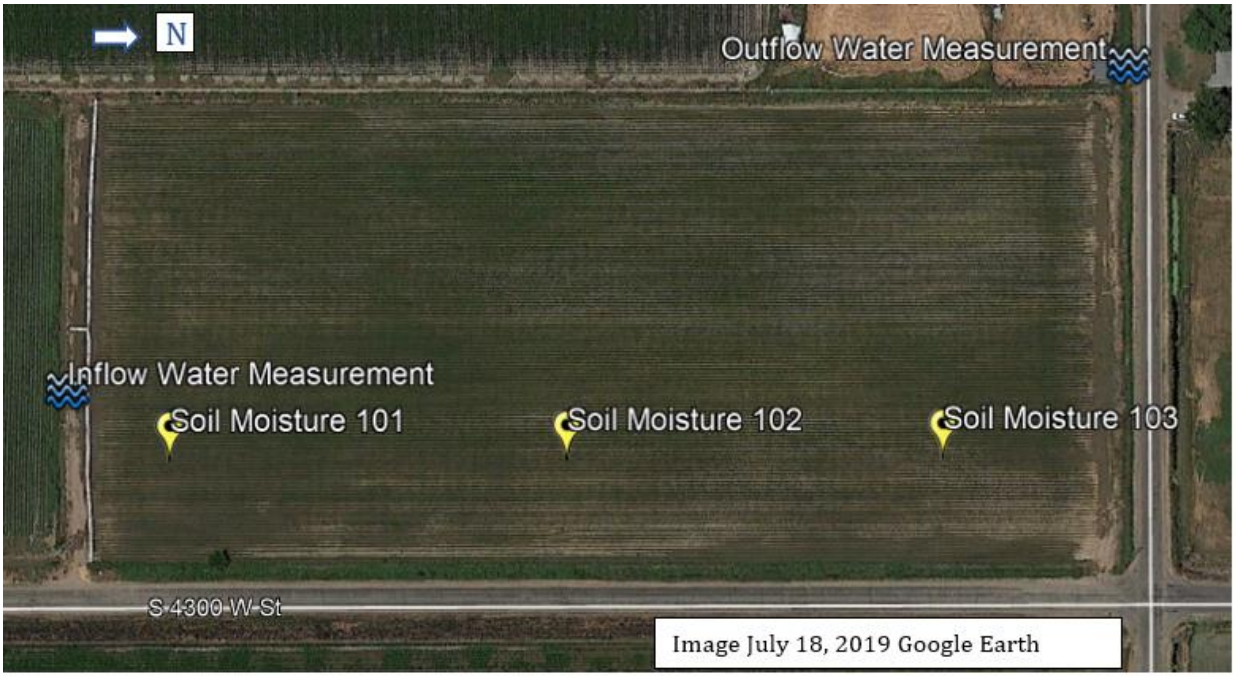

Figure 3. West Weber surface irrigated onion field. Lay flat PVC pipe can be seen on left edge of image.

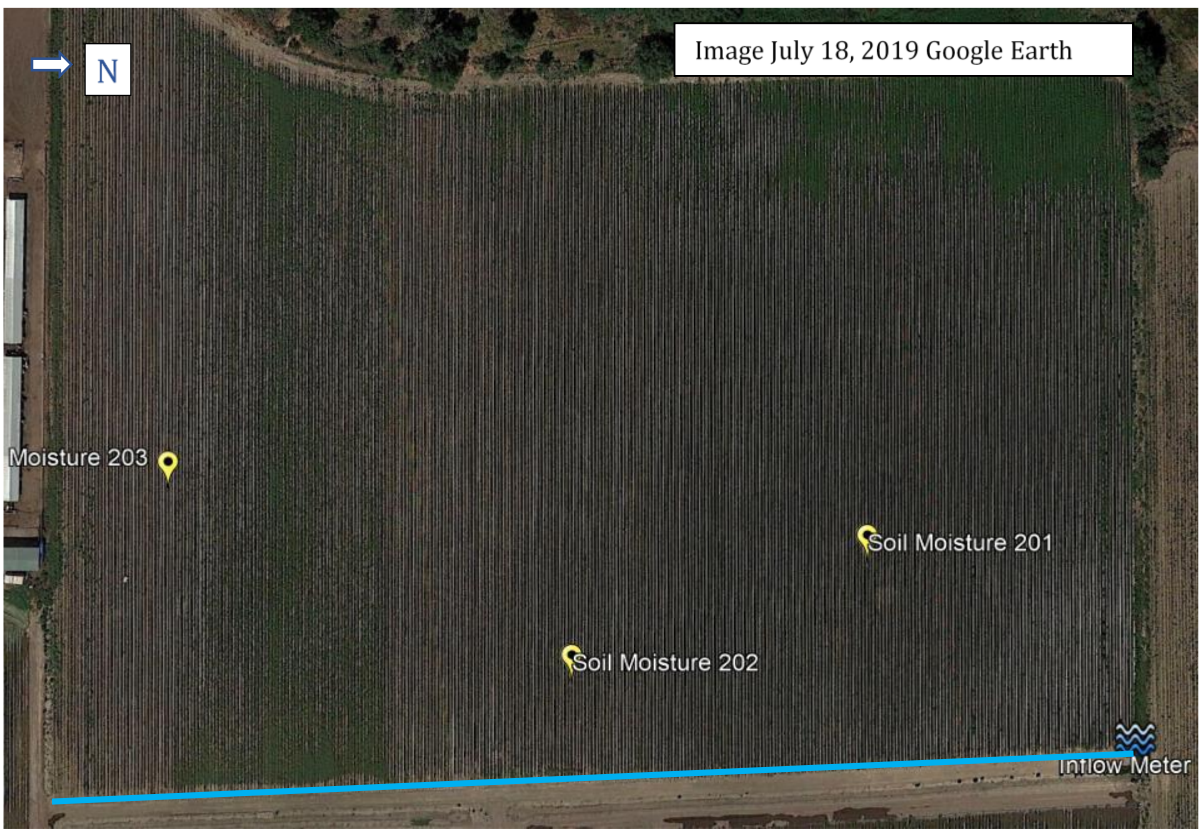

Figure 4. West Weber drip irrigated field. The drip PVC lay-flat manifold is indicated by the line at the bottom of the image.

The spring of 2019 had more rain than normal making timely planting difficult. Ideally, onions would be seeded in late March or early April, in 2019 many farmers were not able to plant until the end of April or early May. The surface irrigated onions were seeded April 27, 2019 with Garnero onions and harvested on September 24, 2019. The surface irrigated onions were drip irrigated to germinate and establish the onions prior to the first surface irrigation in June. The drip irrigated onions were seeded at various times in the earlier part of April with Joaquin onions and harvested on August 23, 2019. For yield comparisons, ideally the drip and surface irrigated onions would be the same variety and planted and harvested close to the same dates. The yield is also a function of irrigation, fertilization, planting density, pest management, harvest date, etc. However, the water use comparison which is a primary objective is valid.

Instrumentation and Data

Consumptive use at the field level includes transpiration by vegetation and evaporation. Evaporation occurs from wet soils, vegetative surfaces, open water, and from water sprayed with sprinkler irrigation. A soil water budget and a surface energy balance using soil surface temperatures is used to estimate ET. Components of the soil water budget are described in the Methodology section. Electronic instrumentation was used to measure and collect data due to the frequency, type, and amount of data collected.

Soil moisture sensors accurately measure soil water at depths greater than a few inches, but do not fully account for the evaporation from the soil surface. To estimate soil surface evaporation an infrared radiometer was used to measure the soil surface temperature. Because evaporation cools the soil surface, an energy balance can then be used estimate evaporation. The energy balance is:

> Evaporation = $R_n - G - H$; where R_n is the net radiation flux, G is the soil heat flux, and H is the sensible heat flux where the fluxes can be expressed a W/m^2.

Water applied to the fields and water leaving the fields is an important aspect of this study. A Semetric™ Ag2000 magnetic flux recording flow meter was installed at the head of the drip system to measure total water applied to the field. Runoff did not occur on the drip irrigation field. The volume of water applied and draining from the furrow irrigated onion field was measured with a Greyline Instrument™ Bigfoot level-velocity transmitter and datalogger recording flow depth and velocity installed in 30” PVC pipes. Figures 6-9 show the daily application and runoff of irrigation water. The days with lower flowrates are due to only partial day irrigation, the flowrate for the drip was recorded every 16 minutes and the flowrate for the surface irrigation was measured every 30 seconds and recorded every hour.

Figure 5. Surface (area-velocity) and pipe flow (electromagnetic) meter.

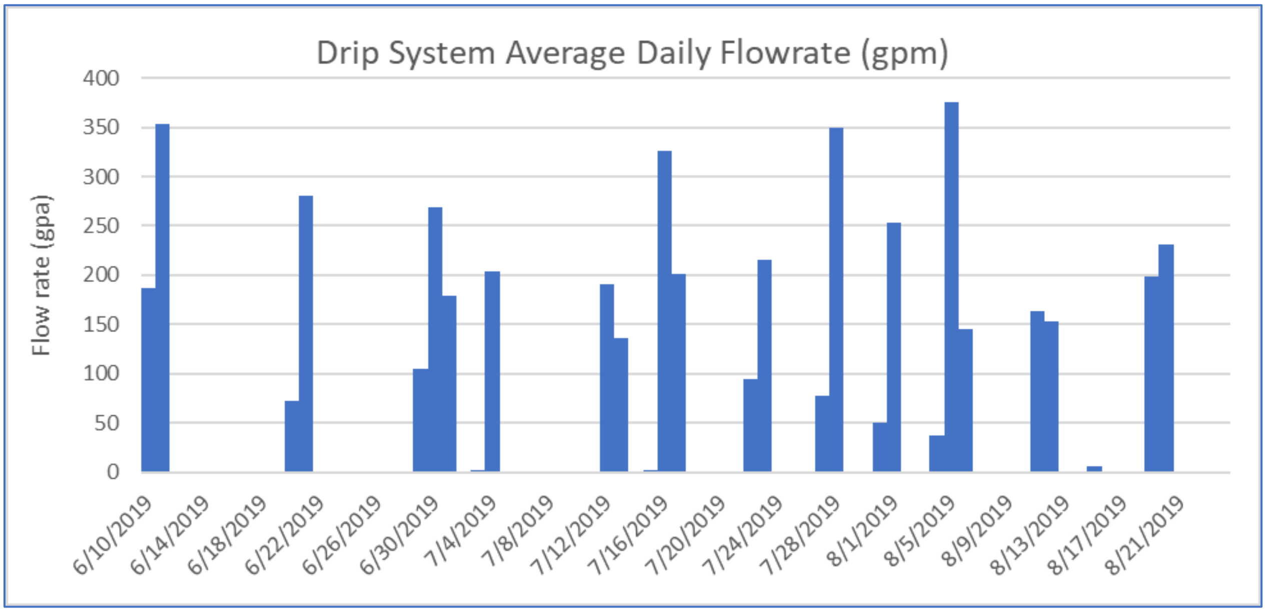

Figure 6. Average daily flow rate of drip irrigation. Average is calculated as the average of 90 flows recorded each day.

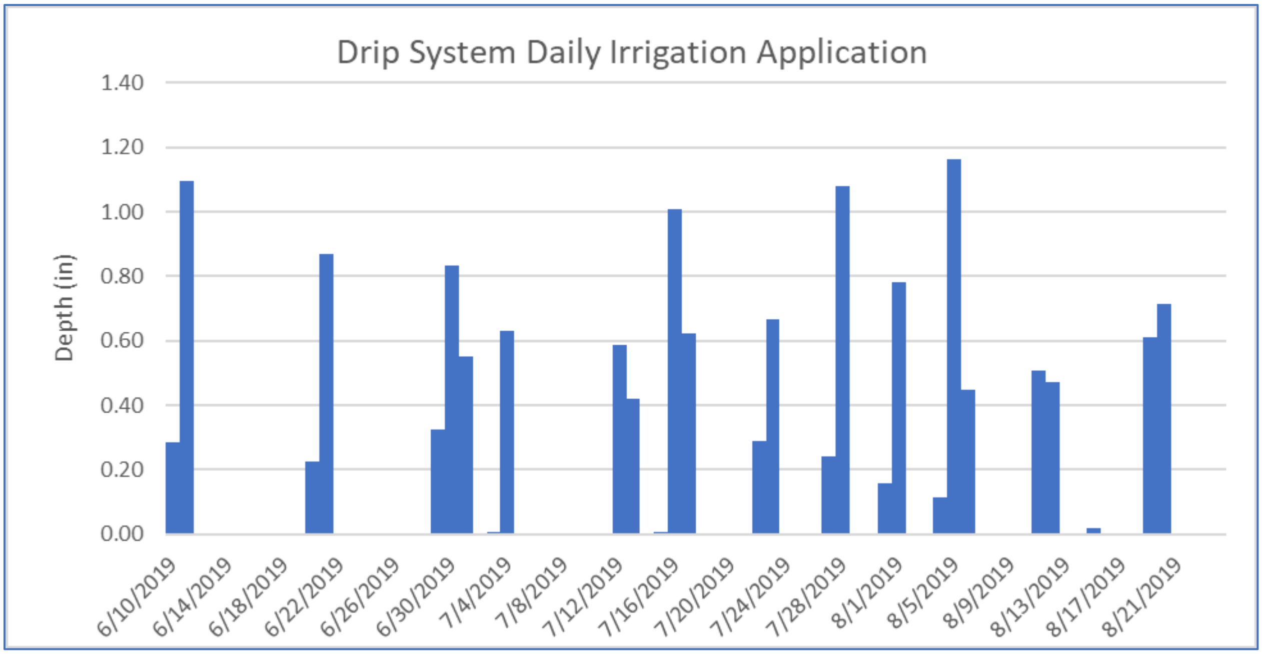

Figure 7. Daily application depths of the drip irrigated field. Calculated from flow volume divided by field area.

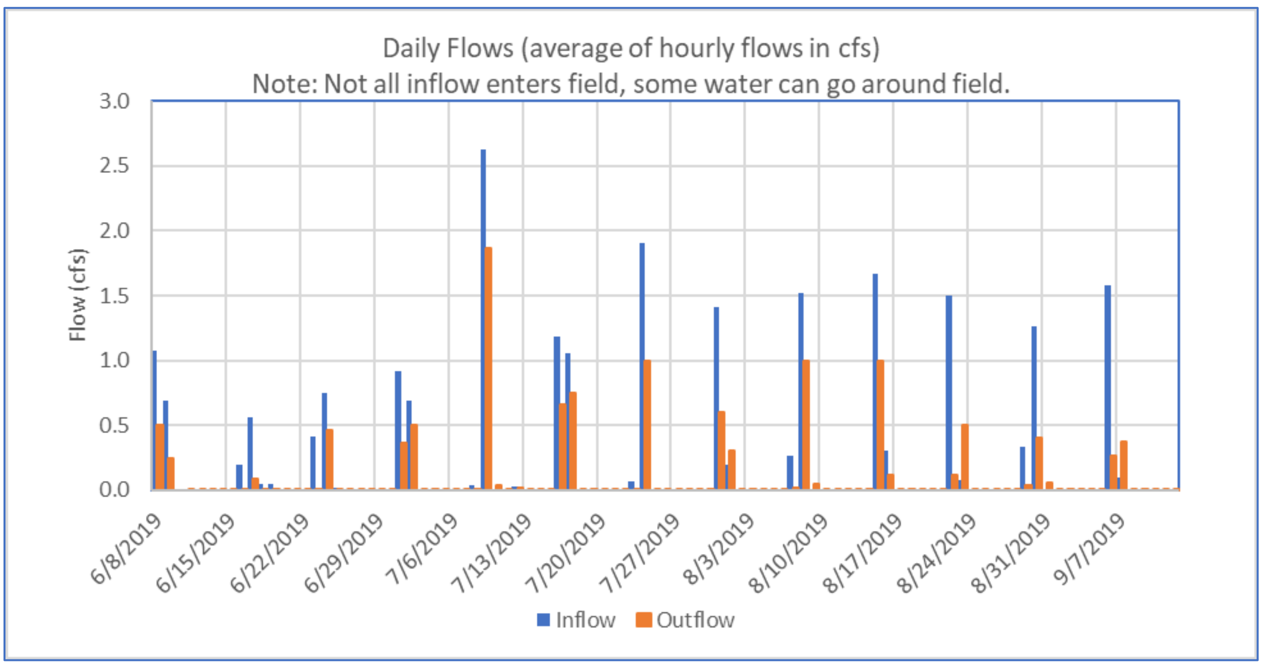

Figure 8. Daily average inflow and outflow of surface irrigated field. Daily average is average of hourly recorded flow rates.

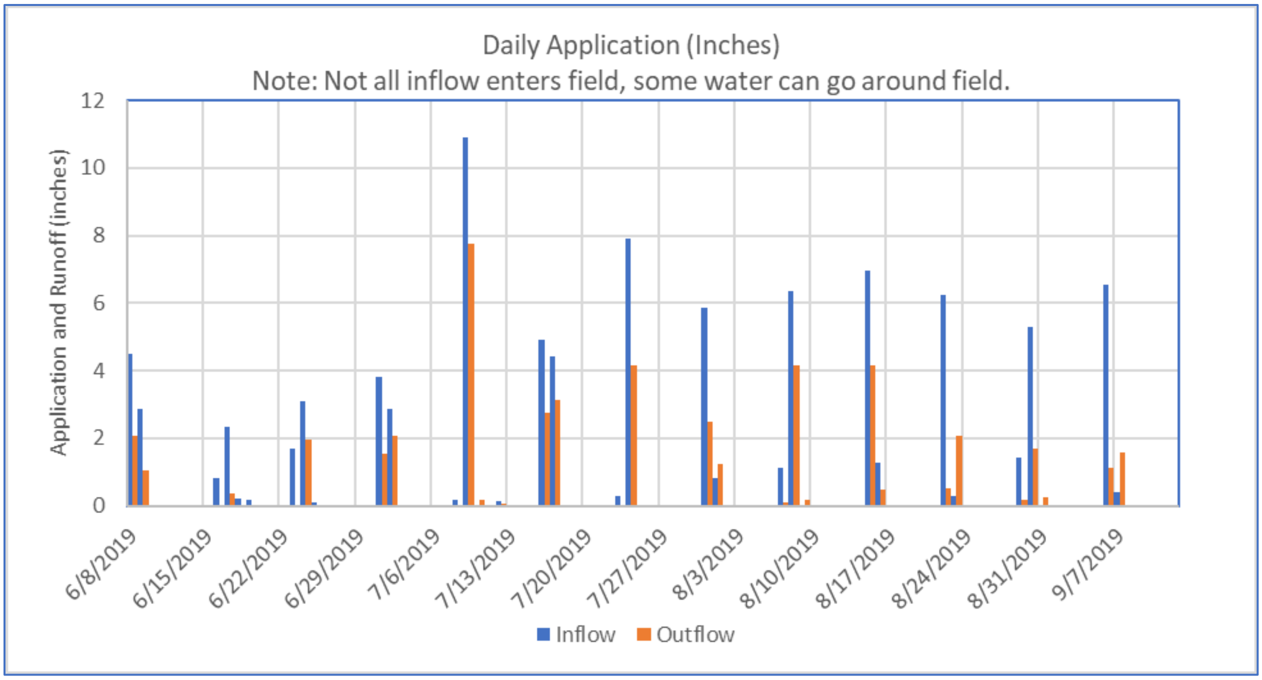

Figure 9. Daily application depths of the surface irrigated field. Calculated from flow volume divided by field area.

The total irrigation for the <u>drip irrigated field was 14.6 inches</u>. There was no runoff and soil moisture sensors indicated that was no deep percolation. The irrigation for the <u>surface irrigated field was measured at 93.8 inches and the total runoff was 47.3 inches for infiltrated irrigation of 46.5 inches.</u> It should be noted that it is possible that not all of the 93.8 inches were diverted to field, because the outflow meter picks up water that flows past the headgate and around the field. Some adjustment to the data were made by correlating increases in soil moisture with timing of application. The flow meter also measures flows that were delivered to a corn field. Based on available field data, these flows were not included in the inflow to the onion field. This flow was separated based on irrigation times provided by the grower and looking at timing of irrigation as identified in soil moisture readings. Due to uncertainty this information was not used to estimate consumptive water use, but does provide a good indication of water delivered to the field.

<u>Soil Moisture Measurement</u>: Soil moisture sensors were installed at three locations in the drip and furrow irrigated fields. Each location had 10 soil moisture sensors (see Figure 10). Three locations were selected in each field to help get representative data. The three locations for the soil moisture sensors in the furrow irrigated field are in upper third, middle third, and lower third of field. Based on past research experience and literature the Acclima TDR 315 sensors were used (Blonquist, et al., 2015 and Schwartz, et al., 2016). The sensors were carefully installed to not disturb the onions and the dataloggers were located about 10 feet from the location of the sensors (Figure 11). The sensors and data loggers recorded moisture, soil temperature, and soil salinity data every half-hour. This data was used to calculate daily ET using the soil water budget. The soil sensors and infrared radiometers were installed after germination and emergence of the onions. The soil sensors were installed by boring a 4” diameter hole between the two double rows on the onion bed. The probes three 6” spikes were installed in undisturbed soil below the onion plants. The infrared radiometer

was mounted on pipe above the onion bed and were set at a height to include a rectangular area that included two furrows and two onion beds. For all sensor locations the stand and health of the onions were not compromised by the soil moisture sensors.

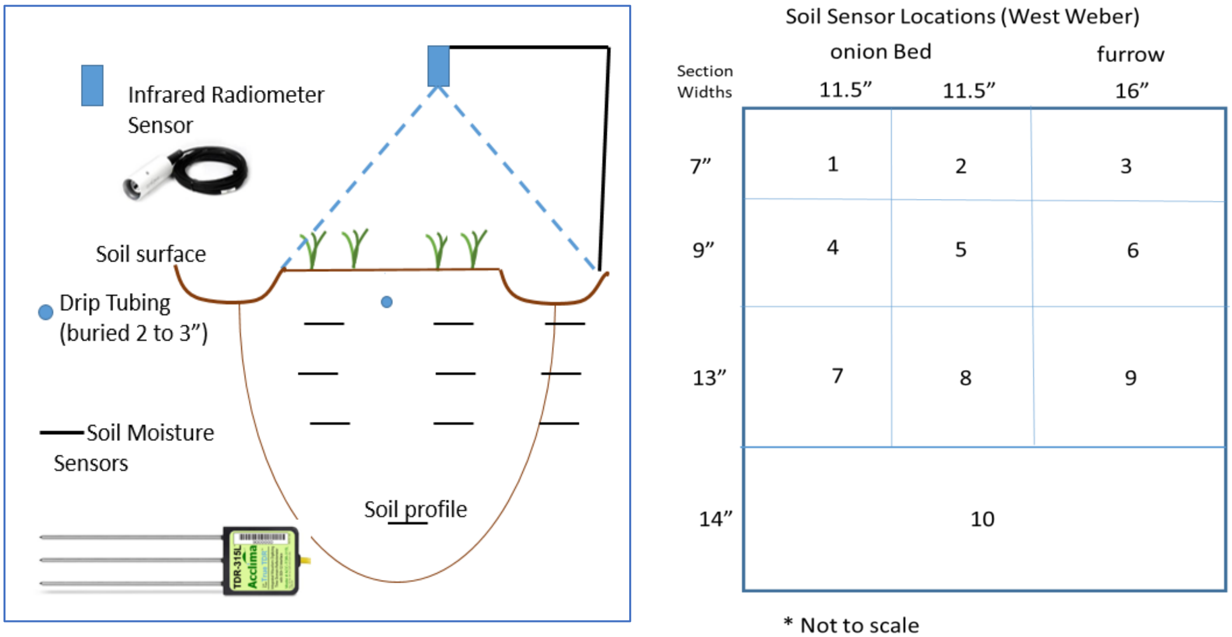

Figure 10. Soil moisture and temperature sensor positioning.

Figure 11. Field installed soil moisture sensors.

<u>Soil Surface Temperature</u>: Non-contact surface temperature measurement using high accuracy Infrared Radiometers were installed at the soil moisture locations in the fields. The data loggers were programmed to take surface soil temperature readings on a 15-minute basis.

<u>Weather Station</u>: A weather station was installed in West Weber near the field locations. The nearest Utah Climate Center weather station is located in a golf course located in an urban area in

Roy, Utah. The weather station includes temperature, humidity, solar radiation, precipitation, and wind velocity and direction.

Field Procedures: An onion producer using sub-surface drip irrigation in Weber County, Utah agreed to cooperate on the project, by allowing the research to be conducted on his production fields. A weather station was set up to obtain data for an energy balance and calculation of ET.

The soil moisture units are percent by volume which was converted to a depth based on the volume soil the sensor represented. All calculations were done using a unit with of 1, so the areas represent by a sensor was based on sensor depth and spacing. Daily ET from the soil moisture was calculated using the soil moisture from midnight to midnight. The half-hour readings were use determine ET patterns during the day. Figure 12 shows the total soil moisture (representing a depth of 43 inches) in the drip. Early in the season some data is missing due to delays from the equipment supplier and some hardware problems. The increase in soil moisture are due to irrigation and/or precipitation and decrease is from ET or drainage. The drip system had no drainage or deep percolation as indicated by the deep soil moisture sensors that were consistent and relatively dry the entire period. For the drip system soil moisture at one location was consistently low and the irrigation as indicated by soil moisture was lower. Figures 13 and 14 show the daily change in soil moisture on a daily basis and then sorted to show day that are most likely ET only and drainage and irrigation.

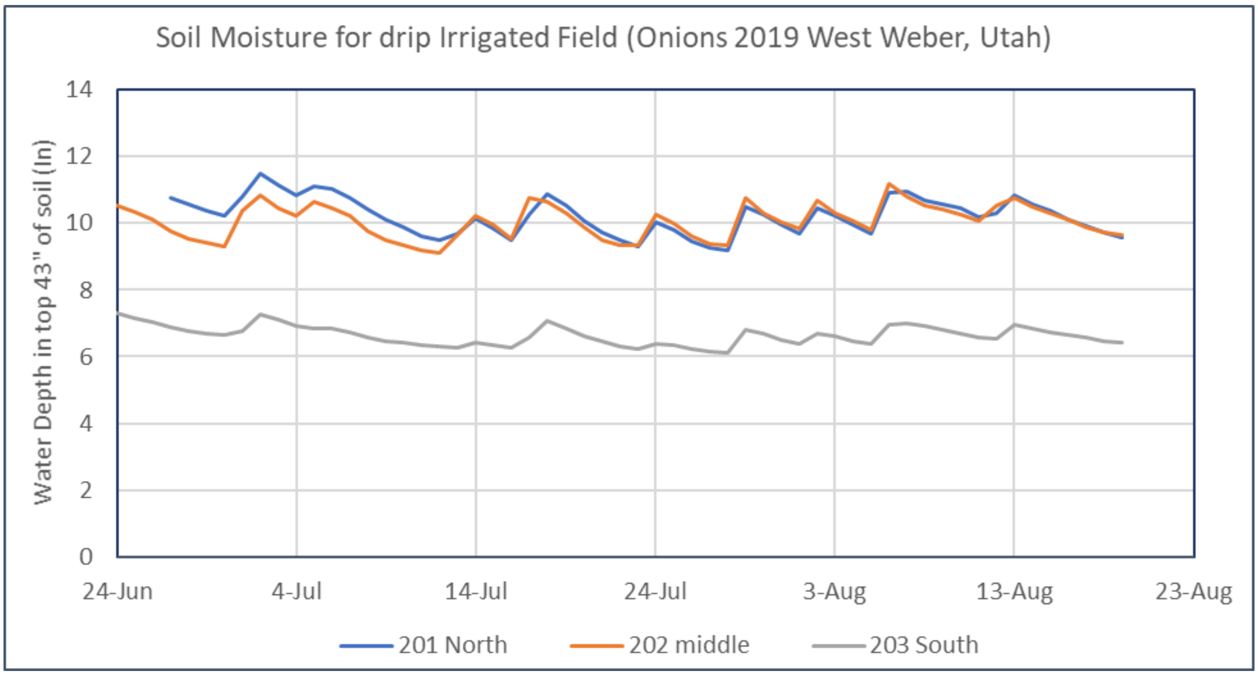

Figure 12. End of day soil moisture for locations in drip irrigated field.

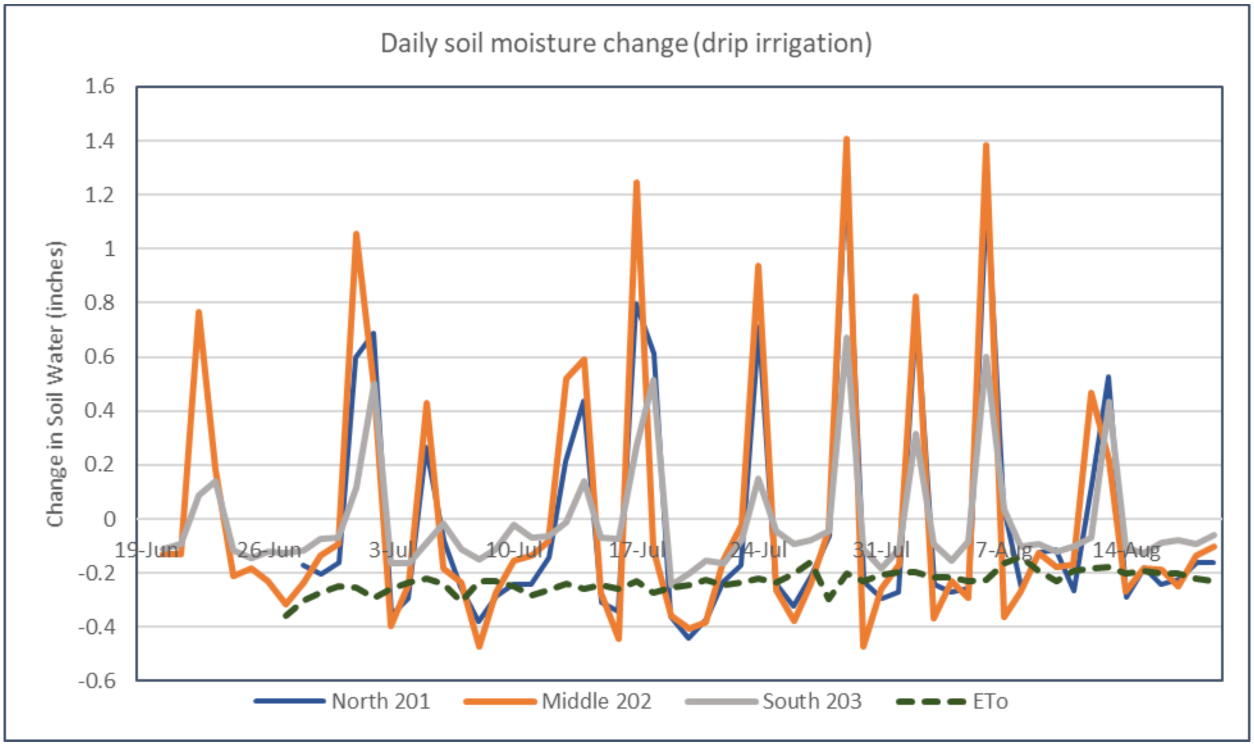

Figure 13. Daily change in soil water for the drip irrigated field. Positive values are increase in soil water (e.g. irrigation) and negative values are decrease soil water from ET and deep percolation.

Figure 14 shows the daily change in soil moisture for surface irrigation field. The soil moisture in the surface irrigation system fluctuated (maximum to minimum) more between irrigations than the drip system. The total soil moisture was higher due to the bottom portion of the soil profile being near saturation the entire season and the soil in the furrow was wetter. Figures 15 show the daily change in soil moisture. Note that drainage and irrigation vary much more for the surface irrigation than for the drip irrigation field. Figure 16 show daily change in soil moisture based on the average of the three soil measurement sites in both the surface and drip irrigated fields. The change in daily soil moisture is much higher for the surface irrigated fields showing more irrigation and drainage.

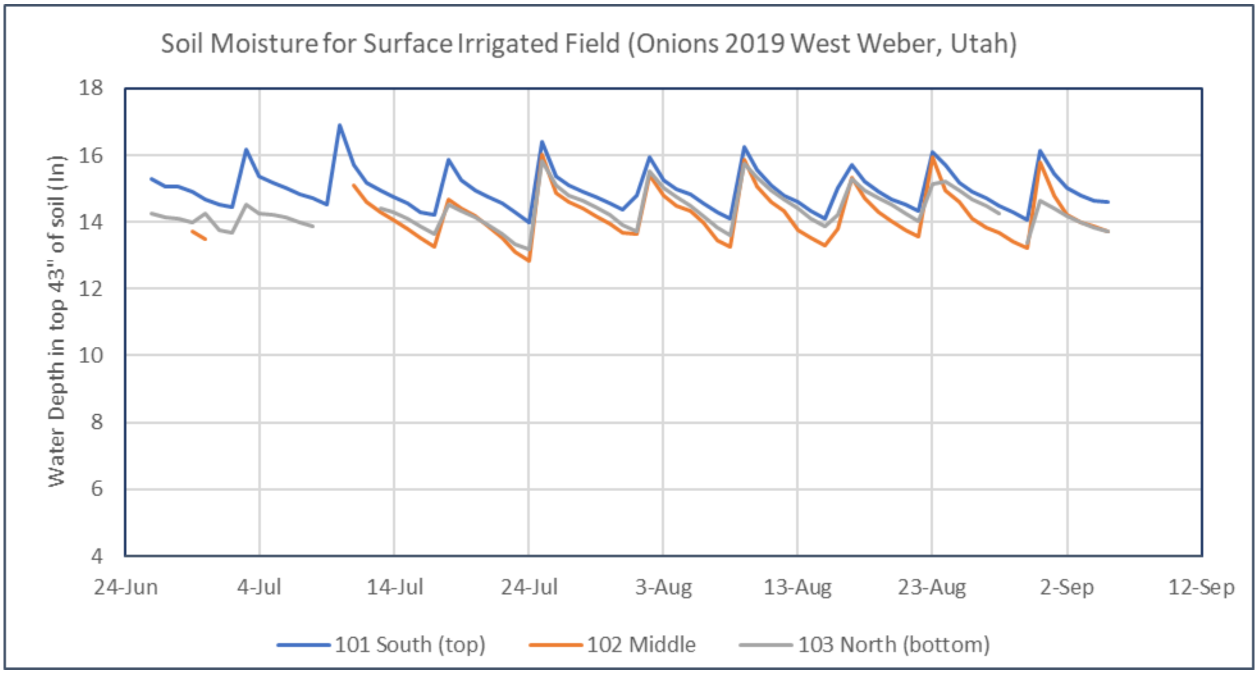

Figure 14. End of day soil moisture for locations in the surface irrigated field.

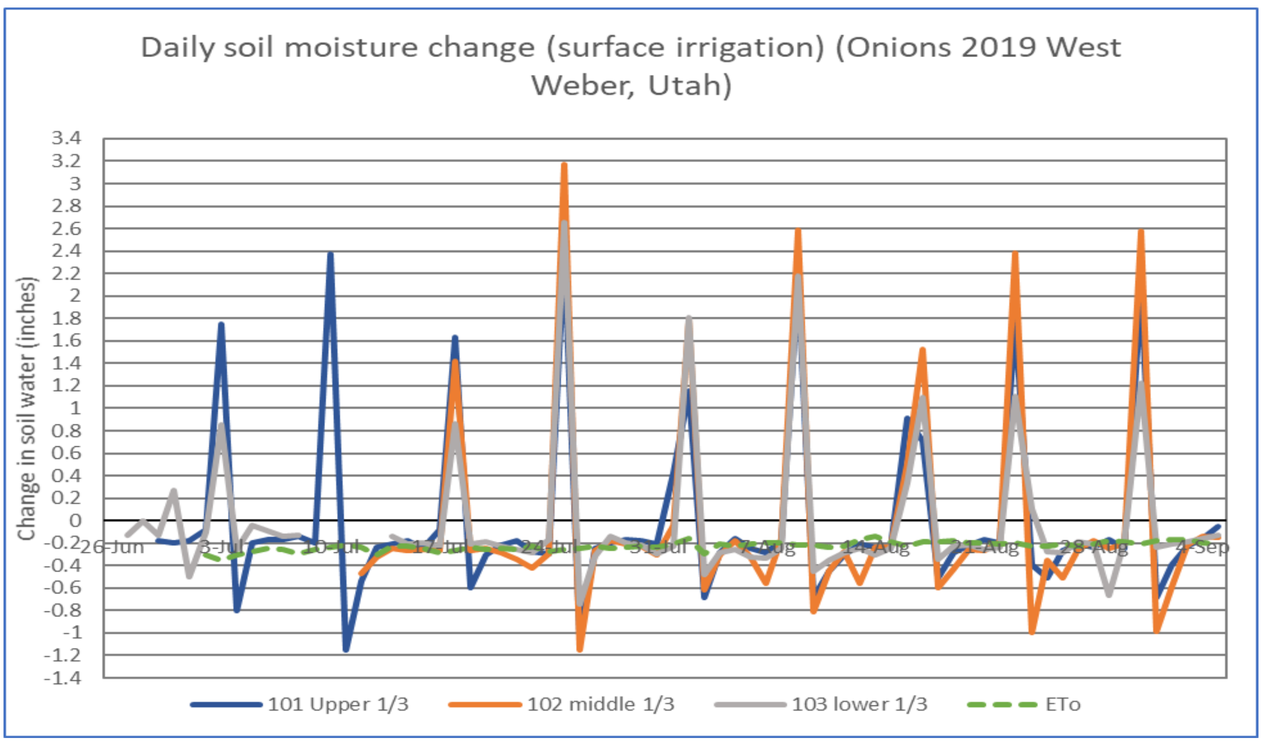

Figure 15. Daily change in soil water for the drip irrigated field. Positive values are increase in soil water (e.g. irrigation) and negative values are decrease soil water from ET and deep percolation.

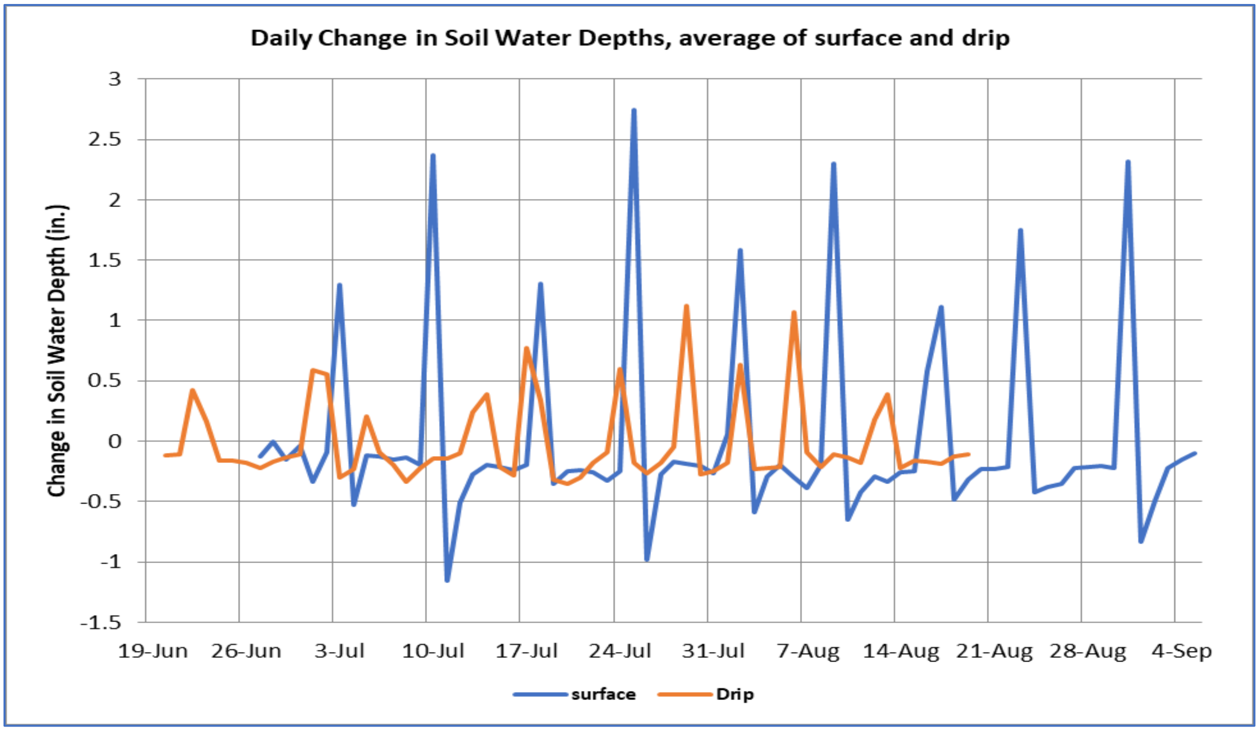

Figure 16. Daily change in soil moisture based on the average of the three soil measurement sites in both the surface and drip irrigated fields.

Figure 17 shows the half-four soil moisture percentages by volume for the 10 sensors at one location in the surface irrigated fields. The figure shows the rapid increase in soil moisture at the time of irrigation. The data shows that nearly all the water use by the onions are in the top 16 inches of soil under the onions. The soil moisture in the furrow decreased a lower rate than the under the furrow. The soil moisture at 22 inches stays near field capacity with an increase during irrigation and then minor drying from drainage and perhaps a small amount of transpiration. The soil moisture at 36 inches is saturated the entire month.

Figure 18 shows the total soil moisture depth (inches) in the top 43 inches of soil on a half-hour time increment. The figure illustrates the method used to estimate deep percolation after an irrigation. The soil moisture increases by 2 to 2.5 inches (although water going to the 36-inch deeper sensor would not register because the soil is saturated (see Figure 17). The figure shows the rapid drainage after the irrigation and then the more constant depletion for onion ET. The dashed lines indicate the time when the change in soil water is primarily ET. The slope of the dash lines ranges from 0.18 inches per day to 0.2 inches per day. The area between the blue solid soil moisture line and the dashed line is deep percolation after irrigation.

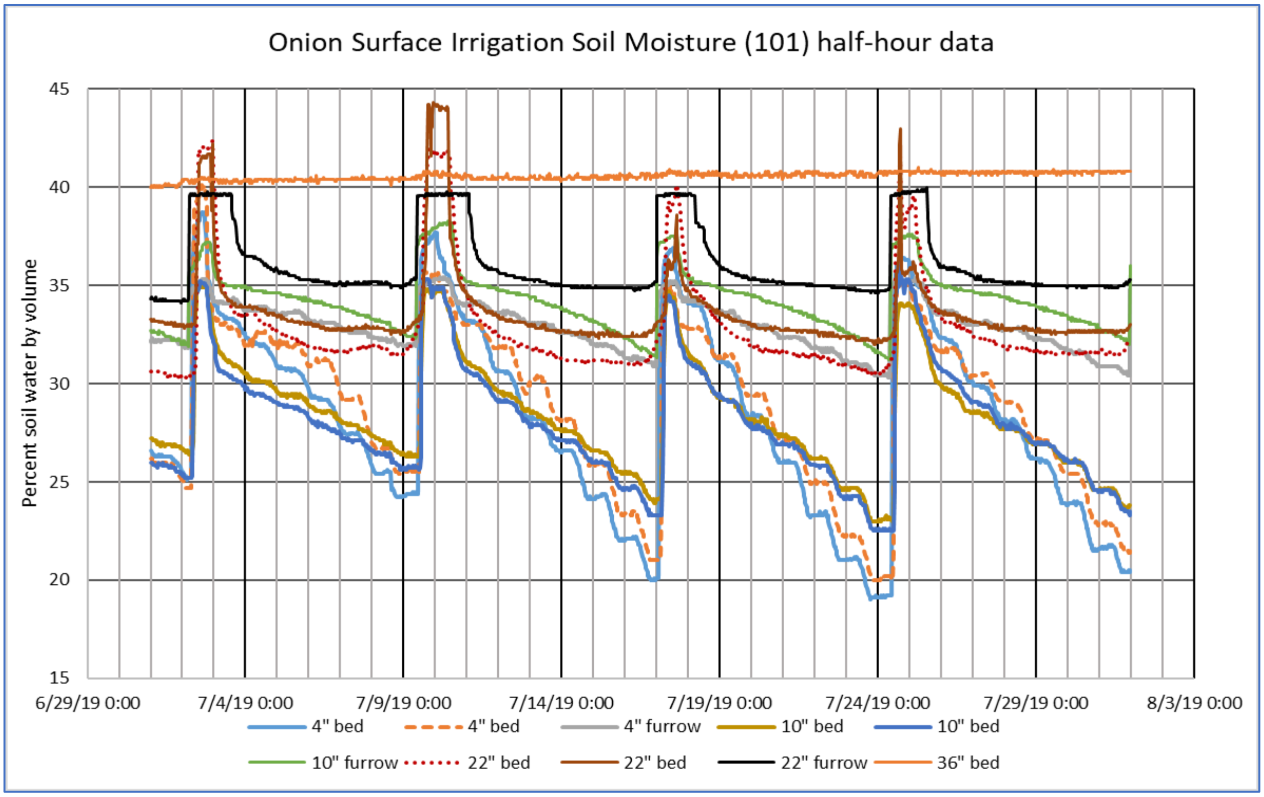

Figure 17. Soil moisture percentage by volume of 10 sensors of surface irrigated onion field (July 2019).

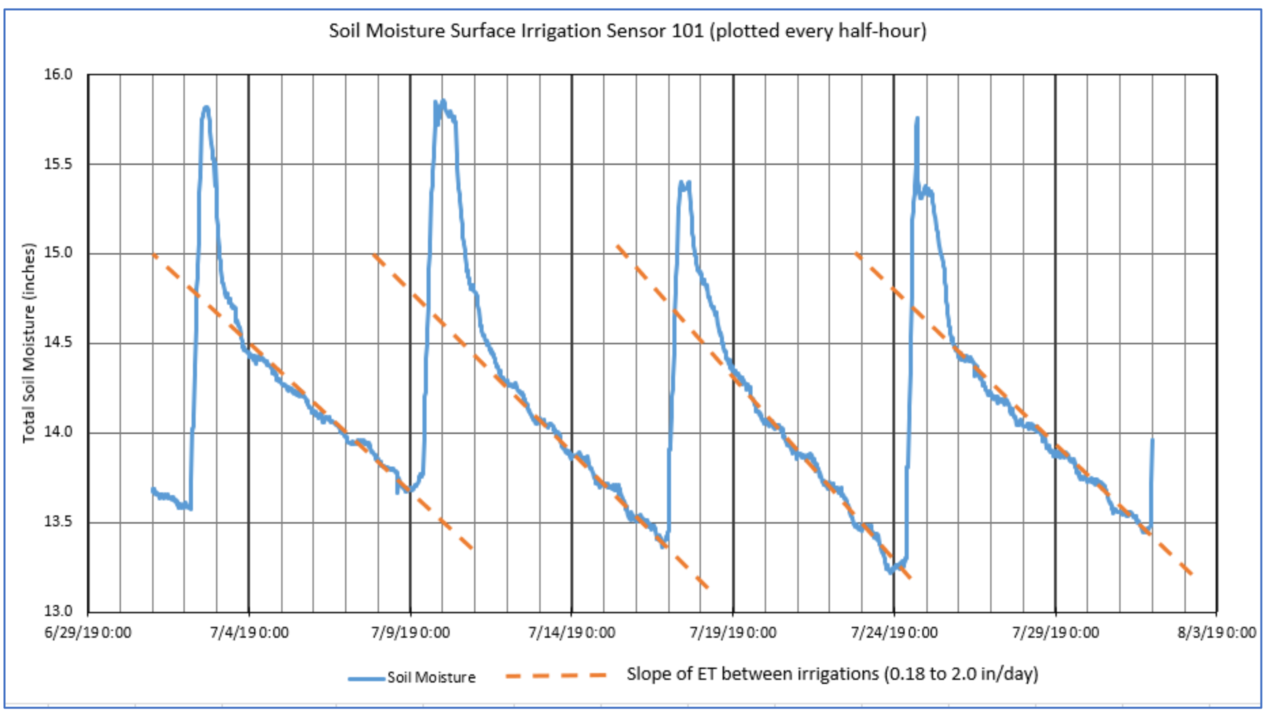

Figure 18. Soil moisture in top 43 inches of soil plotted every half-hour for July 2019. The dashed line shows ET rate after irrigation drainage.

Figure 19 shows the average (three locations each field) daily change in soil water for top 16 inches of the soil (4" and 10" depth sensor below furrow) in the furrow for both furrow and drip irrigated fields. The soil moisture in the drip irrigated furrow stays nearly constant and the soil moisture in the furrow irrigated field increases after each irrigation and then dries out. The soil water evaporation between irrigations accounts for a significant portion of the additional depletion from surface irrigated onion fields, as compared to drip irrigation. The drip irrigation events do not add water to the soil below the furrows.

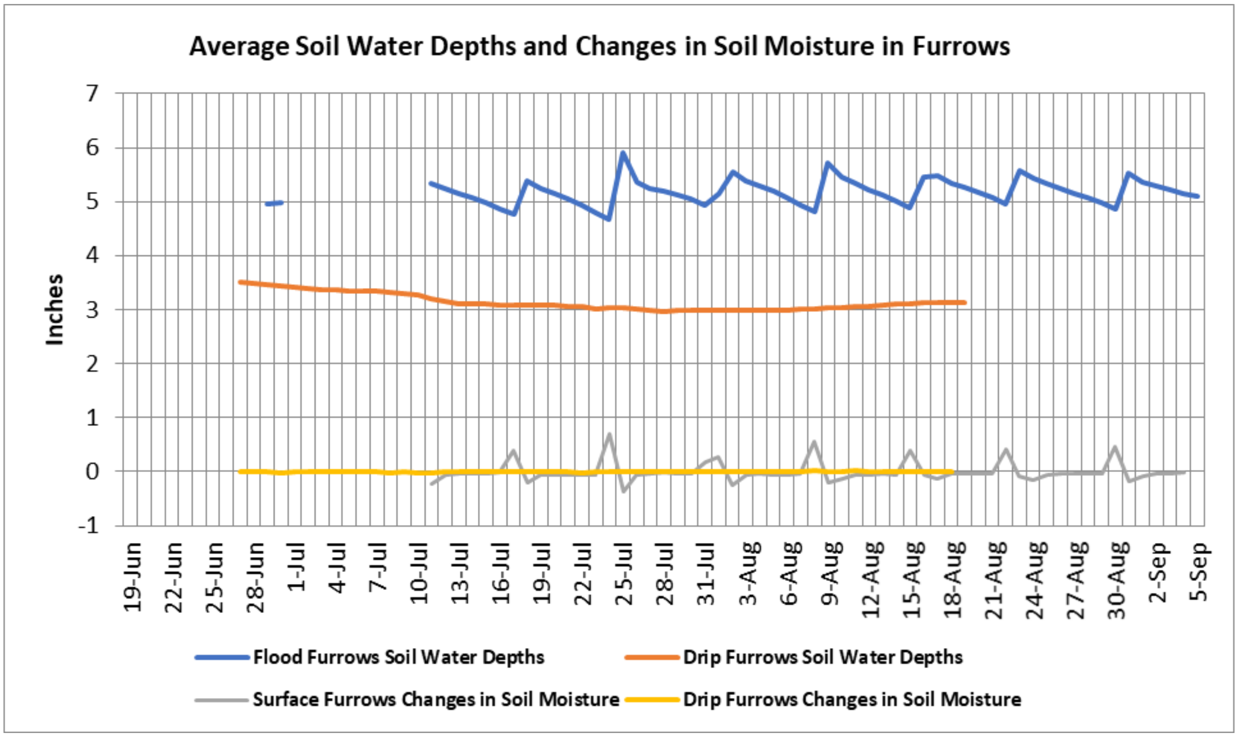

Figure 19. Average (three locations each field) daily change in soil water for top 16 inches of the soil in the furrow for both furrow and drip irrigated fields.

Soil surface temperatures

Drip irrigation usually wets only the onion bed soil and not the furrow soil. The difference in soil surface and canopy temperatures are an indication of the evaporation from the soil surface. Figures 20 and 21 show the maximum and minimum surface soil temperature for the furrow and drip irrigated onions. The average of minimum daily soil temperatures for the furrow irrigated are 1.3°F cooler drip irrigated field (Figure 22). The average of maximum daily soil temperatures for the furrow irrigated are 10.5°F cooler drip irrigated field (Figure 22). The cooler temperatures on the furrow irrigated are a result of evaporation from the wet soil surfaces. The shallow soil moisture sensors measure most of the soil moisture leaving as evaporation, but the estimate can be refined using the soil surface temperature and an energy balance. This analysis has not been completed, but will be incorporated into the final results.

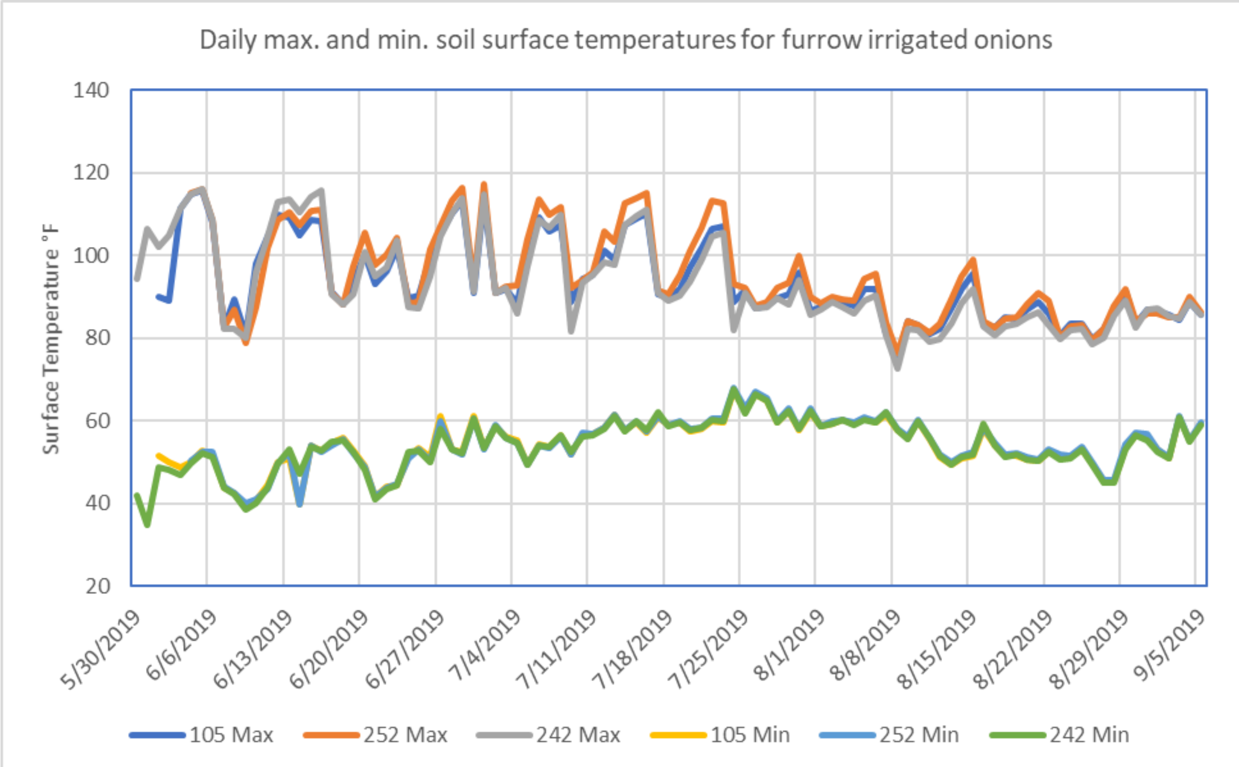

Figure 20. Maximum and minimum daily soil/vegetation surface temperatures for the drip irrigated onion field.

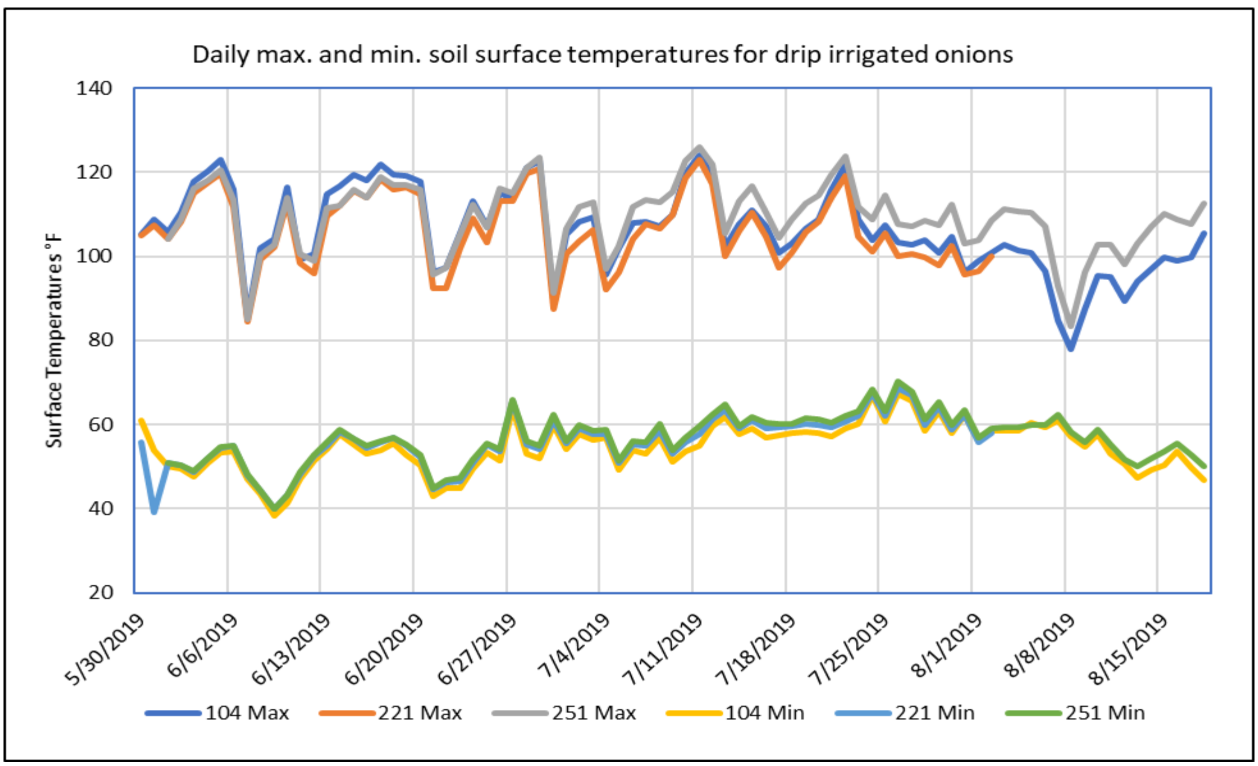

Figure 21. Maximum and minimum daily soil/vegetation surface temperatures for the surface irrigated onion field.

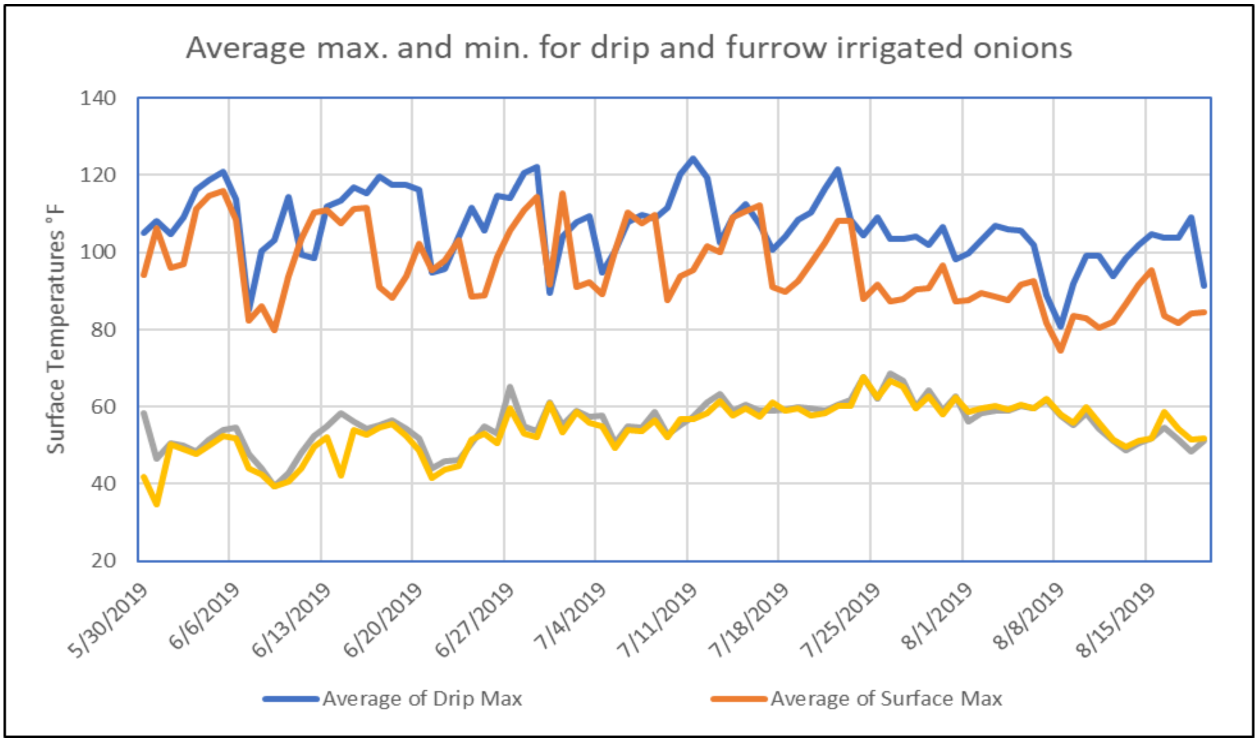

Figure 22. Average (of three sensors in each field) daily maximum and minimum soil/vegetation surface temperatures for the drip surface irrigated onion field.

Onion Yield

Onions yields are dependent on the interaction of many variables, such as soils, seedbed preparation, weather (temperature, precipitation, hail storms, etc.), planting dates, seed germination rate, onion variety, plant population rate, fertility, weeds, pests, diseases, harvest dates, irrigation amounts and schedule, etc. Many farmers state that drip irrigation provides greater yields and returns due to more precise water management capabilities, better germination and establishment, increased ability to conduct field operations as needed due to drier furrows, lower fertilizer needs, more uniform irrigation resulting more uniform onion growth and size. The acreage of drip irrigation of onions has been increasing in northern Utah and other states due to the advantages of drip irrigation.

Tables 2 and 3 show the yield sampling results for the drip and surface irrigated fields. The field both had excellent yields. The yield of the surface irrigated field was higher. Several factors should be considered before making conclusions. Unfortunately, due to the very wet spring that impacted onion planting, a surface and drip irrigated field with the same onion variety and planting date were not available. Additionally, the surface irrigated field was also irrigated with a drip irrigation system for the first two irrigation to help germinate and establish the onions. The yields are an important factor, but not the primary objective of the study is to determine the difference in water depletion.

Table 2. Sample yields of drip irrigated onions.

Drip Irrigation							
	Units	Onion bulb diameter (inches)					
		<2.25	3	3.5	4	4.0+	Total
North	blubs/ac.	3,909	33,508	65,898	26,806	2,792	132,914
	lbs./ac.	1,059	17,511	53,418	27,313	3,300	102,601
Middle	blubs/ac.	4,468	43,560	36,300	29,040	2,234	115,602
	lbs./ac.	837	21,624	28,298	28,396	2,881	82,036
South (not sampled)	blubs/ac.						
	lbs./ac.						
Drip Irrigation Average	blubs/ac.	4,188	38,534	51,099	27,923	2,513	124,258
	lbs./ac.	948	19,567	40,858	27,854	3,091	92,319
	bags/ac.	19.0	391.3	817.2	557.1	61.8	1,846.4
	% size	3.4%	31.0%	41.1%	22.5%	2.0%	

Table 3. Sample yields of drip surface irrigated onions.

Surface Irrigation							
	Units	Onion bulb diameter (inches)					
		<2.25	3	3.5	4	4.0+	Total
North	blubs/ac.	12,286	53,612	66,457	44,677	2,234	179,266
	lbs./ac.	1,958	26,697	49,355	44,134	3,103	125,246
Middle	blubs/ac.	13,962	35,742	64,223	53,054	5,026	172,006
	lbs./ac.	2,734	16,279	54,330	48,468	7,093	128,904
South	blubs/ac.	7,260	21,780	57,522	52,495	13,403	152,460
	lbs./ac.	2,044	11,157	40,833	55,660	18,126	127,820
Surface Irrigation Average	blubs/ac.	11,169	37,045	62,734	50,075	6,888	167,911
	lbs./ac.	2,245	18,044	48,173	49,420	9,441	127,323
	bags/ac.	44.9	360.9	963.5	988.4	188.8	2,546.5
	% size	6.7%	22.1%	37.4%	29.8%	4.1%	

RESULTS

A summary of the water use is presented in Table 4. The table summarizes the results from methodology and data presented in this report. In 2019 for the fields evaluated, the irrigation diversion and depletion for the drip irrigation system was significantly less that for surface.

- The surface irrigation diversion was over 6 times higher than the drip irrigation system. This was in part due to the fixed irrigation schedule and delivery amounts for the irrigation company. The drip system pumped from a water source that provided flexibility.
- The drip irrigation depletion was 11.4 inches less (only 56 percent of surface) than the surface irrigated field. The factor that contributed most to the difference is the evaporation of water from the increase wet soil surface in the surface irrigated field. Another factor was the later planting and harvest date of the surface irrigated onions.
- The total depletion from the drip irrigated field (precipitation and irrigation) was 11.26 inches less (64 percent of surface field) than the surface irrigated field. The reduced depletion is an important aspect for agriculture water optimization.
- The onion yield of the surface irrigated field was higher. As previously discussed yields are a result irrigation and many other factors, so the yield differences can not be directly attributed to the irrigation method. One factor that stands out is the plant population rate (onions/acre) is 35 percent higher in the surface irrigated field.

The continuation of the study in 2020 is addressing some of the difference that occurred in 2019. For example, the onion variety is the same for all four fields are being evaluated and the planting dates were very close.

Table 4. Summary of furrow irrigation and drip irrigation water use for West Weber study in 2019.

Description	Furrow Irrigation	Drip Irrigation
Irrigations		
Irrigation period (fist-last)	May 6 - June 1 (drip) June 10 - Sep 7 (furrow) (124 days)	June 9 to August 21 (73 days)
Number of irrigations	2 drip 13 furrow	12
Gross application (in.)	2.1 drip 94 flood	14.6
Runoff (in.)	47	0
Infiltrated water (in.)	47	0
Estimate deep percolation (in.)	21	0
Change in soil water (in.)	0	0
Precipitation (before irrigation)	0.05	4.11
Precipitation (during irrigation period)	6.05	0.99
Total precipitation	6.1	5.1
Water Use		
April ET estimate from ETo and Kc	0.3	1.4
May ET estimate from ETo and Kc	2.9	2.9
ET from irrigation (June - Harvest)	26	14.6
ET from precipitation (June-harvest)	1.95	0.99
Seasonal ET	**31.15**	**19.89**
Cropping Dates		
Planting date	April 27	April 5-15 (various dates)
Lift date	September 24	August 23-25
Total planting to harvest (days)	150	136
Harvest date	October 16-17	September 2-3
Yield Samples		
Yield (lbs./ac.)	127,323	92,319 (avg.) 102,601 (max.)
Onion count (lbs./ac.)	167,911	124,258
Harvest notes	Yield was taken at time of lifting.	Only two yield samples were obtained before harvest. Onions had dried for about 1 week

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ESTIMATION OF EVAPOTRANSPIRATION USING UAV IMAGERY

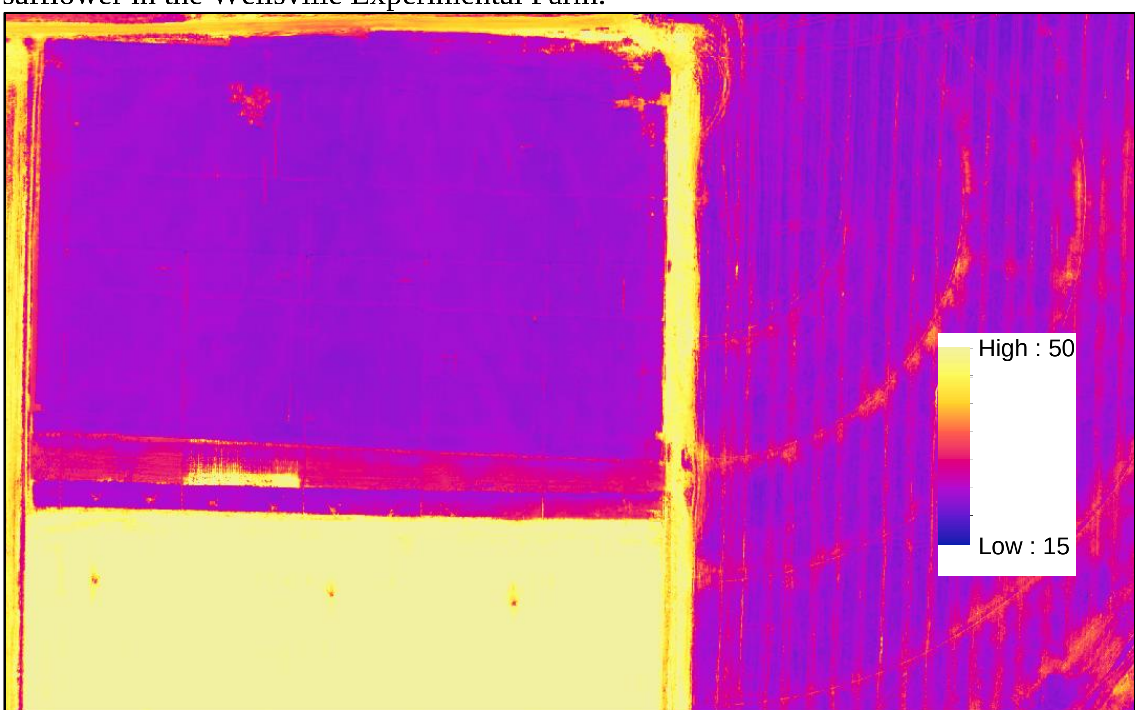
Information provided by Dr. Alfonso Torres-Rua

Agriculture Water Optimization remote sensing work conducted at the Wellsville irrigation farm in 2019. The very wet spring in 2019 did not provide the degree of irrigation difference between plots. The work is continuing in 2020 and the difference in irrigation system and scheduling are much more apparent.

Estimation of Evapotranspiration using UAV imagery

In 2019 two UAV flights were conducted over the Utah State University Wellsville Experimental Farm, in Cache Valley. USU' AggieAir UAV Service Center collected optical and thermal imagery two separate dates: August 13th and September 25th at local solar noon. Main installed crops are corn, safflower and alfalfa. Examples of captured optical and thermal information are presented below:

Fig. 1. Top August 13th and (bottom) September 25th optical imagery of the corn, alfalfa and safflower in the Wellsville Experimental Farm.



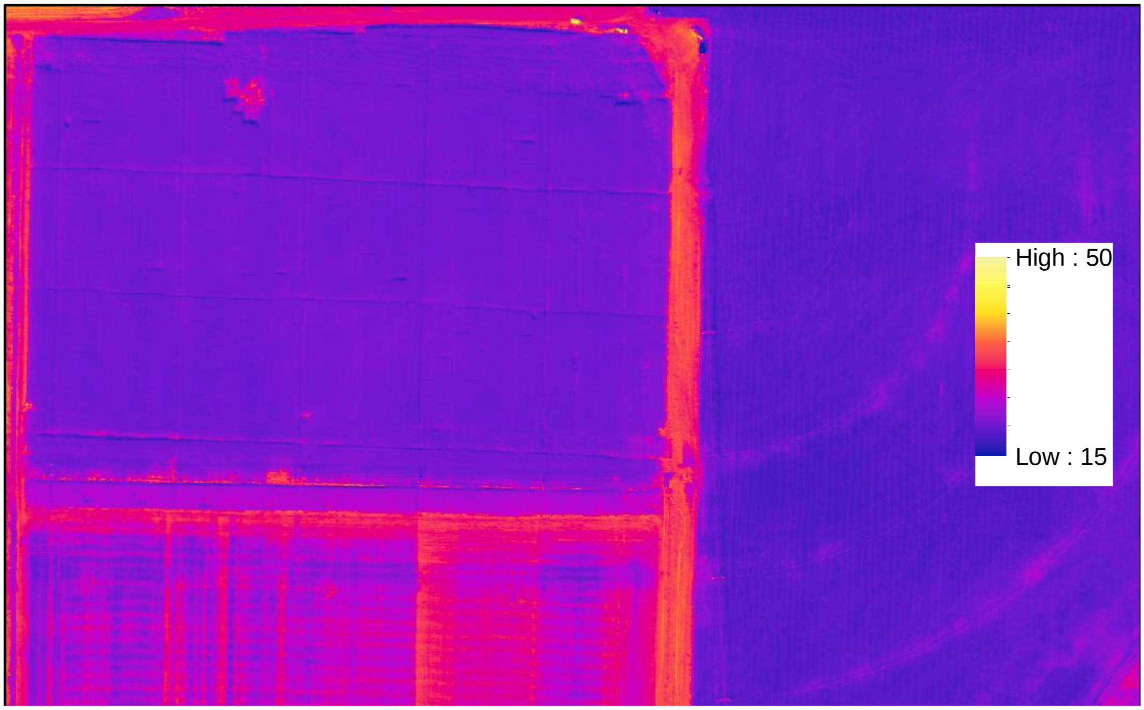


Fig. 2. Top August 13th and (bottom) September 25th thermal imagery (in Celsius degrees) of the corn, alfalfa and safflower in the Wellsville Experimental Farm.

Between August 13th and September 25th significant crop development occurred for all crops. Planted corn and safflower shows signs of maturity at the later date, while alfalfa shows a dense and homogeneous foliage or biomass. In addition, the thermal imagery shows lower temperatures at September 25th for corn and alfalfa. For corn, at both dates, we see homogeneous greenness and temperature values, with very small variation across the planted area. The lower temperatures in corn and alfalfa is due to the canopy/biomass development consequently larger water content in leaves. For sap flower, a decrease in greenness and temperature is evident from August to September. The changes are reflecting senescence conditions and reduced biomass water content. This is evident in the NDVI and scaled temperatures as shown below:

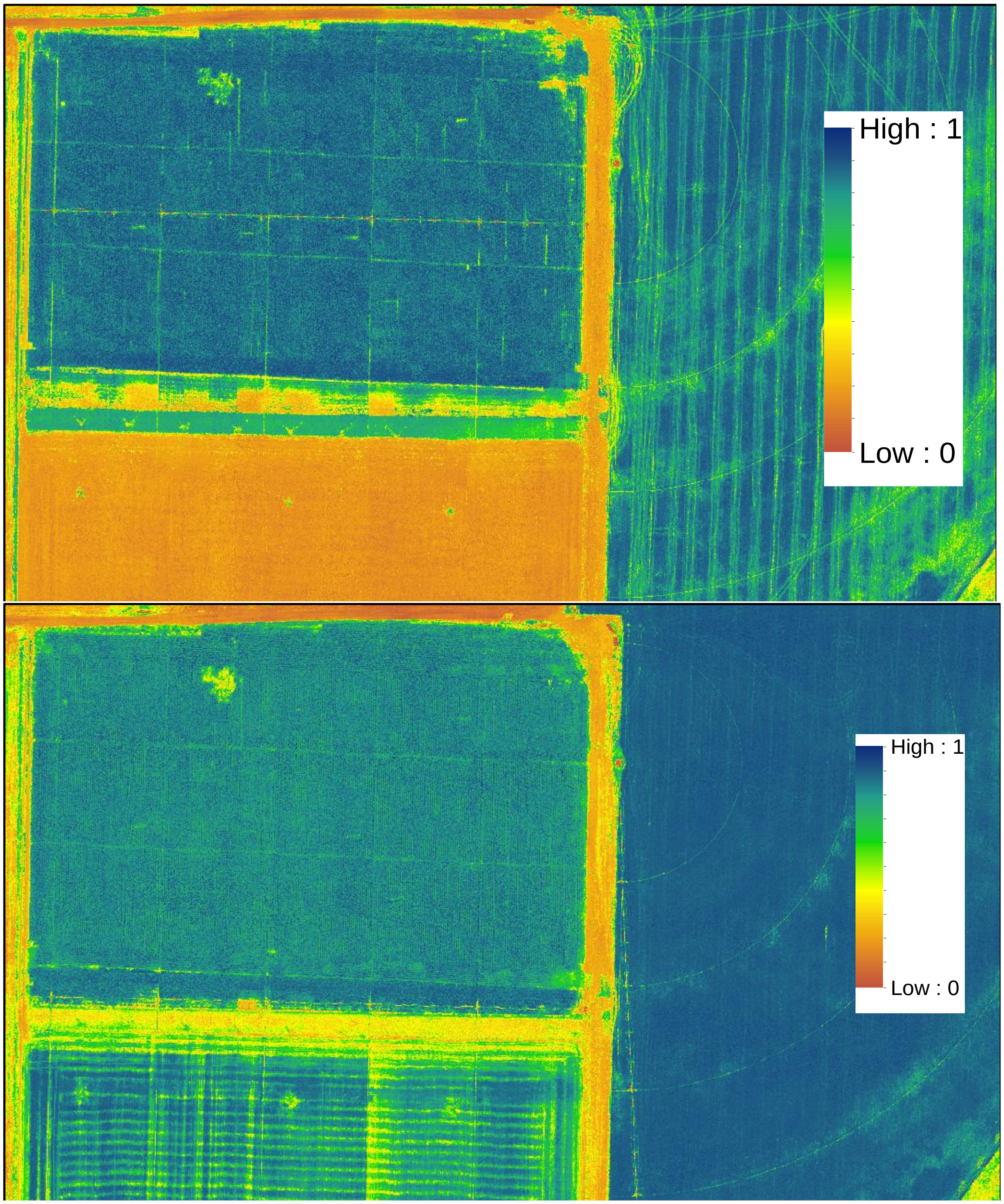


Fig. 3 NDVI results for (top) August 13th and (bottom) September 25th optical imagery of the corn, alfalfa and safflower in the Wellsville Experimental Farm.

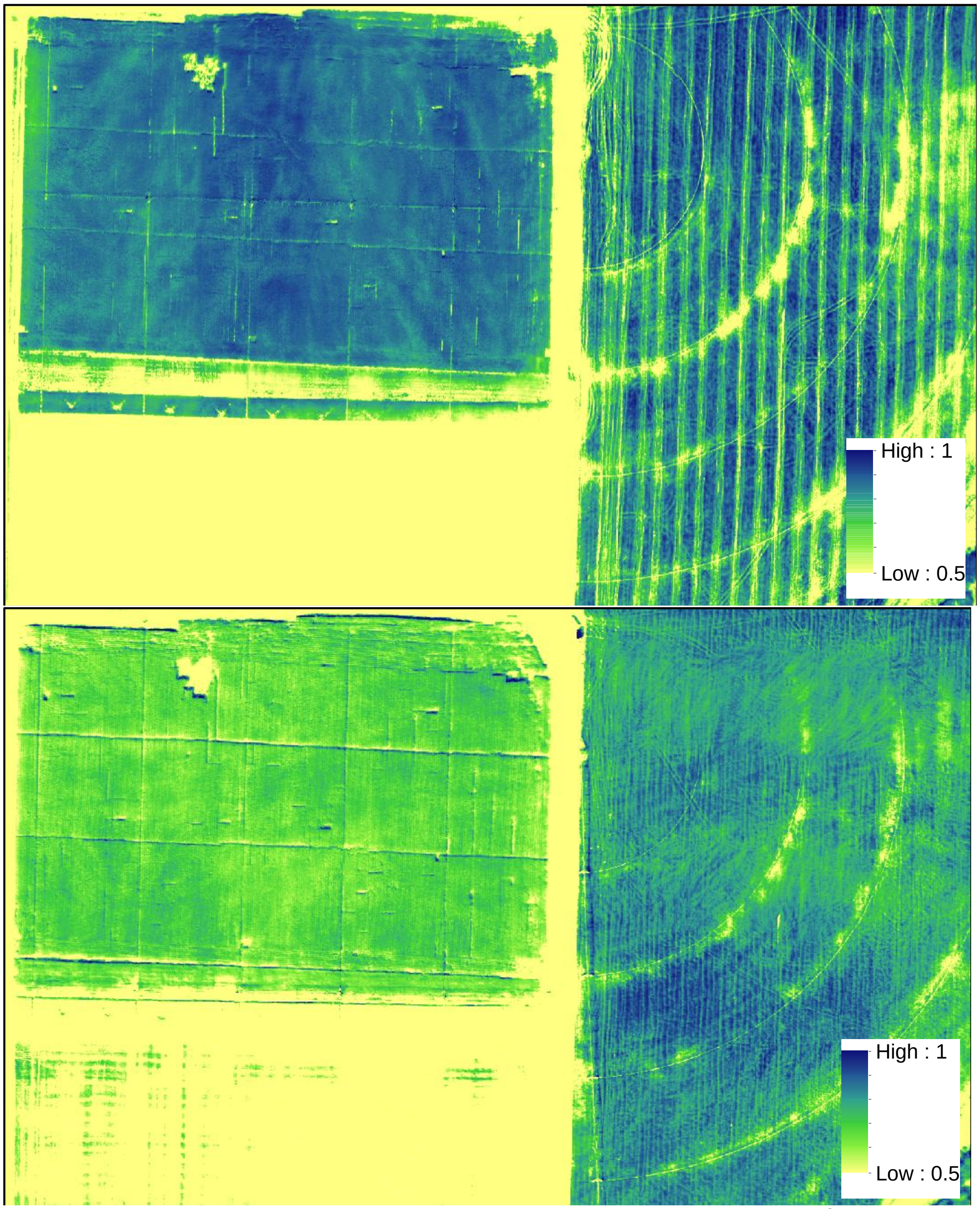


Fig. 4. Thermal scaling (1 is colder, 0.5 is hotter) for(top) August 13th and (bottom) September 25th optical imagery of the corn, alfalfa and safflower in the Wellsville Experimental Farm

The NDVI images describe the overall health of the three crops. Corn shows senescence conditions in September (overall decrease in NDVI), while alfalfa has increased NDVI. In the corn area, thermal scaling images shows a clear colder region in the central area in August, which has disappeared in September. For safflower the vegetation is dry with a significant temperature reduction in September. The difference between thermal scaling images is because the lower temperatures in alfalfa in September.

To determine the crop water use of these three crops, an actual evapotranspiration model called Two-Source Surface Energy Balance (TSEB) was applied to the UAV NDVI and thermal information using climatological data from the Utah Climate Center AgWeather "ExpFarm" weather station, located within two miles from the Wellsville Experimental. Initial Evapotranspiration results are shown below. The resulting ET images were obtained at a resolution of 2m/pixel.

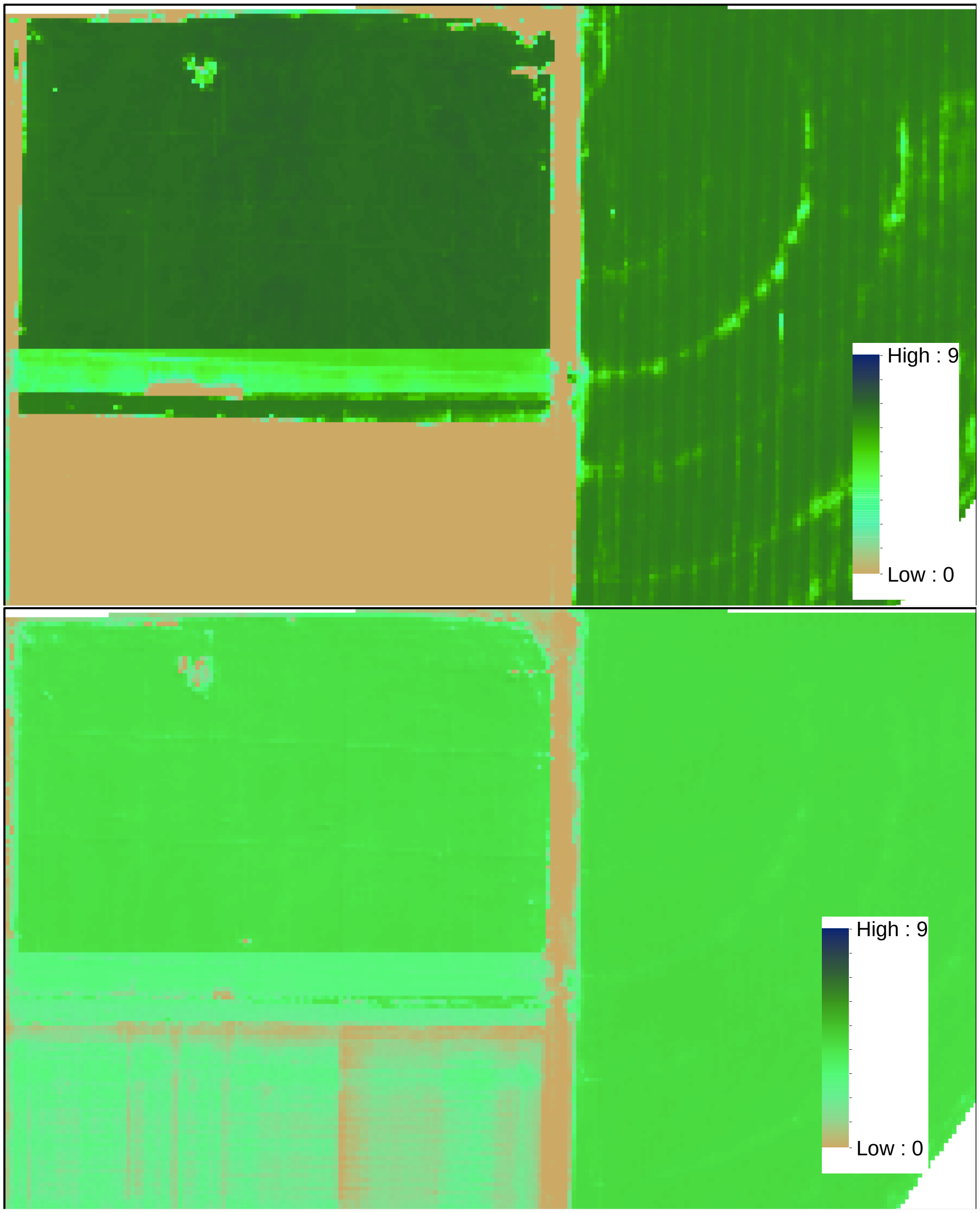


Fig. 5. Actual Evapotranspiration Map for the August and September dates. Units in mm/day

The evapotranspiration maps show higher daily rates for August than for September. In the August image, corn and safflower had a slightly higher rate than alfalfa, while for September all three crops have a similar ET rate. An initial comparison between referential ET is presented below.

Date	ETr mm/d	Corn mm/d	Safflower mm/d	Alfalfa mm/d
2019 Aug 13	8.26	6.64	5.29	6.35
2019 Sept 25	4.91	4.00	2.02	4.28

Further steps in the project are a further evaluation of the weather station information, refinement of the TSEB ET estimation, and comparison against soil moisture measurements in the Wellsville Experimental site.

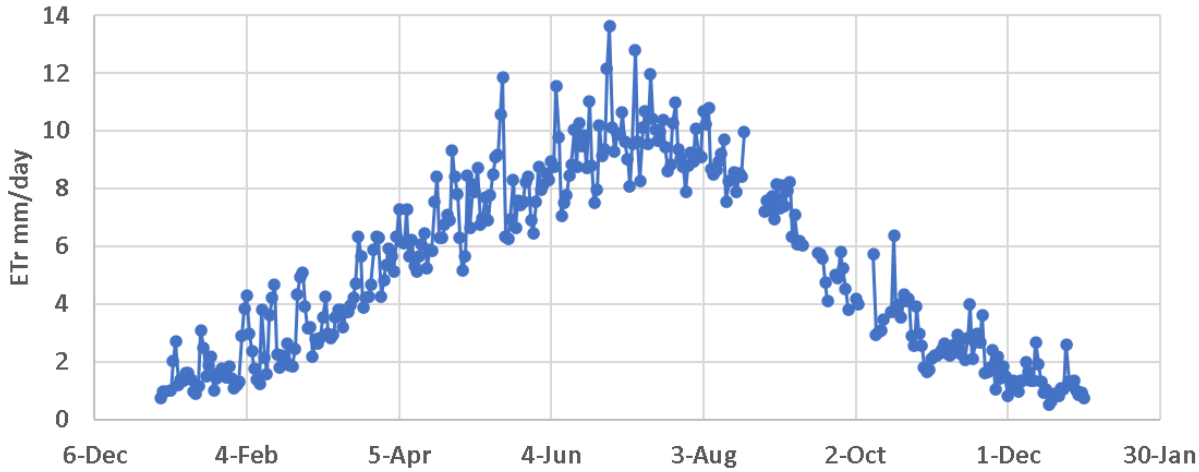


Fig. 6 Utah Climate Center daily referential ET for the AgWeather "ExpFarm" weather station, as calculated using the software Ref-ET software.